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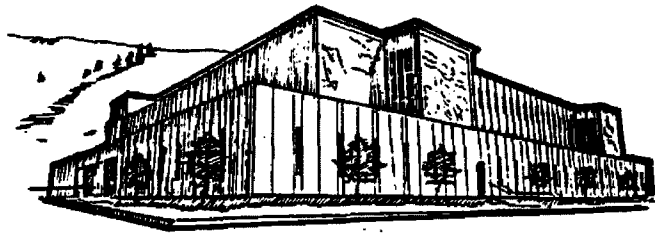
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University of  
**Montana**



**IMMEDIATE EFFECTS OF "CONTRACT-RELAX AND  
AGONIST CONTRACTION" ON ACTIVE AND PASSIVE  
HIP ABDUCTION RANGE OF MOTION**

**By**

**Shawn O. Henry**

**B.S., Eastern Montana College, 1988**

**Presented in partial fulfillment**

**of the requirements for the degree of**


**Master of Science**

**University of Montana, 1991**

**Approved by**

  
Chairman, Board of Examiners

  
Dean, Graduate School

  
Date

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The University of Montana Graduate School

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Dean, Graduate School

Henry, Shawn O., M.S., June 1991

Exercise Physiology

**Immediate Effects of "Contract-Relax and Agonist Contraction" on Active and Passive Hip Abduction Range of Motion (62 pp.)**

Director: Richard L. Gajdosik, Ph.D. 

The purpose of this study was to investigate if a specific proprioceptor neuromuscular facilitation technique for stretching, "Contract-Relax and Agonist Contraction" (CRAC), had significant immediate effects on hip abduction range of motion (ROM). Both active ROM and passive ROM measurements were used to assess the effects of CRAC. Twenty-four healthy women between the age of 18 and 35 volunteered to participate in the one-shot study. The subjects were randomly assigned to either a control group (n=12) or to an experimental group (n=12). The lower limbs were marked with tape over bony landmarks and photography was used to document the position of limb abduction. The experimental group underwent the CRAC protocol, which consisted of contracting the adductor musculature isometrically against an external resistance for 5 seconds, then contracting the abductor musculature (agonist) submaximally for 5 seconds in an attempt to abduct farther. This "cycle" was repeated three times. Endpoint ROM was determined by one of two criteria: 1) EMG activity or 2) verbalization of maximal ROM by the subject. The results were analyzed using an ANOVA for repeated measures. Although the active and passive ROM increased for the experimental group compared to the control group, the ANOVA showed no statistically significant differences between the experimental and control groups. There was a significant interaction between groups ( $p < 0.05$ ). Additional research is needed to clarify the immediate and long term effects of the CRAC protocol for increasing hip abduction ROM.

## **ACKNOWLEDGEMENTS**

**Much appreciation is owed to Richard L. Gajdosik for his invaluable inspiration, guidance and motivation in the pursuit of this accomplishment. Deep thanks also go to Brian J. Sharkey, Sharon Dinkel Uhlig, and Richard van den Pol for their helpful contributions in the refinement and completion of this thesis.**



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## **CHAPTER 1**

### **INTRODUCTION**

**Flexibility and Range of Motion (ROM) have long been studied by physical educators, coaches, therapists, and other professionals interested in rehabilitation or optimal physical performance. Normal ROM is considered important in the effective and efficient performance of daily activities: Exceptional ROM seems to be necessary for success in many types of athletic competition (i.e., gymnastics, dance, martial arts) (Cornelius & Hinson, 1980; Prentice, 1983; Schultz, 1979). Range of motion is considered one of the main components of physical fitness, others being muscular strength, muscular endurance, and coordination. In fact, ROM tests are now included in most popular physical fitness batteries such as the test endorsed by the American Alliance of Physical & Health Education, Recreation, and Dance (AAPHERD).**

**Since the common implementation of stretching as part of fitness programs, it has been accepted that specific stretching exercises increase ROM. Historically, ballistic and static stretches have been the most prevalent. However, in the mid 1950's Proprioceptive Neuromuscular Facilitation (PNF) techniques were developed by Kabat for rehabilitation of paralytic patients**

(Holt, Travis, & Okita, 1970). These PNF techniques included a unique approach to increasing ROM which involved a maximal contraction of the antagonist (muscle to be stretched) followed immediately by a concentric contraction of the agonist. Part of the basis of PNF, muscle facilitation and inhibition, was described by Sherrington in the early 1900's (Sherrington, 1906; Sherrington, 1953). Knott and Voss (1965) expanded the application of PNF to people without paralysis and found the stretching method was very successful (Holt, Travis, & Okita, 1970). However, PNF stretching protocols are still relatively new and there is a need to add information to the growing database. Much research has been conducted using the hamstrings, lower back muscles, and soleus (Condon & Hutton, 1986; Cornelius & Hinson, 1980; Entyre & Lee, 1988; Gajdosik, Giuliani, & Bohannon, 1990; Guissard, Duchateau, & Hainaut, 1989; Hardy, 1985; Hartley-O'Brien, 1980). Comparatively little research has been done studying ROM of hip abduction (primary muscles involved are the adductor's). This "gap" of knowledge was addressed by testing the immediate effects of a PNF stretching protocol on active and passive ROM of hip abduction in females.

### **Statement of the Problem and Hypothesis**

The purpose of this study was to examine the immediate effects of the Proprioceptive Neuromuscular Facilitation stretching protocol of Contract-Relax and Agonist Contraction, or CRAC, on active and passive hip abduction range

of motion in normal, healthy women between the ages of 18 and 35 years.

The specific aims of this project were to:

- 1) Determine the efficacy of a PNF stretching protocol for increasing active and passive ROM and
- 2) Add to the present data base, providing information on hip abduction ROM and the effects of CRAC (PNF protocol).

A null hypothesis, stating that there will not be a significant difference between the experimental group and the control group with regard to ROM, was selected for this study.

### **The Delimitations**

The study only investigated the efficacy of one specific PNF protocol (CRAC). The study did not investigate the viability of other stretching techniques (i.e., ballistic, static, or other forms of PNF) nor did it seek to determine the long term effects of stretching on ROM. Furthermore, the study did not involve any joint action other than hip abduction ROM, nor any population other than healthy women (18-35 yrs).



## **Operational Definitions**

For the purposes of this study, several operational definitions were used.

**Range of Motion** - The amount of mobility possible about a joint, or joints, measured in degrees.

**Active Range of Motion** - The degree of mobility possible about a joint or joints using only "internal" force provided by the subject's own musculature.

**Passive Range of Motion** - The degree of mobility possible about a joint or joints using an external force (or resistance) to maximally lengthen the musculotendinous structures and thus obtain maximum range of motion.

**CRAC - (Contract-Relax and Agonist Contraction)** A PNF stretching protocol in which the antagonist is maximally contracted isometrically for 5 seconds, then relaxed for 5 seconds. During this "relax" phase the agonist is maximally contracted in an effort to further stretch the antagonist. A 30 second recovery period is allowed, after which the cycle is repeated.

## **Abbreviations**

**CRAC** - Contract-Relax and Agonist Contract

**PNF** - Proprioceptive Neuromuscular Facilitation

**ROM** - Range Of Motion

### **Assumptions**

One basic assumption of this study was that each subject exhibited normal active and passive ROM during the time of testing. It is known that ROM can fluctuate because of many factors (i.e., muscle temperature, fatigue, soreness) but these variables were not studied in this research project (Henricson, Fredrickson, & Person, 1984; Lehmann, Masock, & Warren, 1970; Sapega, Quendenfeld, & Moyer, 1981; Warren, Lehmann, & Koblanski, 1971).

## **CHAPTER 2**

### **REVIEW OF LITERATURE**

#### **Flexibility Versus Range of Motion**

Flexibility is an often misused word, even in "educated" circles. Flexibility is synonymous with passive compliance and is the ratio of the change in muscle length ( $\Delta L$ ) to the change in muscle tension ( $\Delta P$ ), or  $\Delta L / \Delta P$ . The passive compliance of a muscle can also be measured by the ratio of the change in angle to the change in torque, or Angle/ Torque (Gajdosik, Giuliani, & Bohannon, 1990). Since passive muscle stiffness is the reciprocal of passive compliance, then stiffness may be defined as the ratio of  $\Delta P / \Delta L$  (Gajdosik, Giuliani, & Bohannon, 1990). Therefore, passive compliance (or flexibility) is not simply ROM; it is the change in resistance in relation to the change in muscle length or joint angle.

Range of motion, on the other hand, only takes into account the movement possible around a joint with no consideration for the resistance encountered. Flexibility is sometimes used when authors actually mean ROM; this is incorrect usage of the word. There are two main types of ROM: 1) Active ROM and 2) Passive ROM. Active ROM is the motion possible about

a joint, or joints, using only the subject's own internal muscular force. In other words, no external force may be used to aid the movement. Active ROM may be limited by resistance from the structures being stretched (i.e., connective tissue, muscles, bony limitations) along with the physiological ability of the agonist muscle to provide sufficient contractive force. Passive ROM is the maximum motion possible using external force to lengthen the musculotendinous structures. Since passive ROM is limited only by the resistance of musculotendinous structures to maximal stretch, it should be greater in magnitude than active ROM.

### **Importance of Flexibility and Range of Motion**

Muscular fitness is comprised of three basic components: muscular strength, muscular endurance, and flexibility or ROM (Moffatt, 1988). Range of motion may be defined as the range of motion possible across a joint or combination of joints. Range of motion is highly specific to each joint of the body (Marshall, Johanson, Wickiewicz, 1980). For instance, a person may have good ROM in the shoulder joint but have relatively poor ROM in the hip joint. Even though there is no conclusive evidence, it is widely accepted that a certain level of ROM is required for optimal physical performance and reducing the risk of injury. However, no one has posited what the minimum ROM requirement would be. Indeed, it would be difficult, if not impossible, to set these requirements because of individual differences and the variance

among physical skills (i.e., football vs. gymnastics). It is known that a high degree of ROM in certain joints is a prerequisite for the performance of skills such as a straight leg press to handstand in gymnastics or a high kick in karate. It would be biomechanically impossible to perform these skills properly without good lower extremity ROM. A weekend jogger, on the other hand, may need less flexibility and ROM than the martial artist to perform his or her respective skill efficiently. The degree of flexibility and ROM desired depends upon the practitioner, the skill being performed, and his or her goals.

### **Measurement and Evaluation of Range of Motion**

Range of motion may be assessed using either direct or indirect data. Direct, or indirect, measurements of ROM should not be confused with direct, or indirect, measurements of muscle length. In regards to muscle length, only absolute measures are direct; all other ROM assessments of muscles (i.e., goniometer, sit & reach, Leighton fleximeter) are indirect measurements used to represent the actual muscle length. The actual muscle length is not often measured in humans, probably because of the difficulty involved and the invasive nature of such studies (Gajdosik & Bohannon, 1987).

Range of motion (not muscle length) may be measured directly using degrees of a circle (total of  $360^\circ$ ), or indirectly using a linear measurement (i.e., ruler). The goniometer is one direct measure which determines the joint angle at both extremes of the ROM. A goniometer is a protractor-like device

that permits measuring the angle in degrees. The goniometer has two arms, one arm fixed at the zero point of the protractor, the other arm remaining movable. The axis of the instrument is centered over the axis of the joint being tested. The arms of the goniometer are then aligned with the body segments on either side of the joint. Range of motion is the difference between the joint angles at the start and end of maximal movement. Error can be introduced if the goniometer axis is not matched to the true joint axis, or if the arms of the instrument are not properly aligned with the longitudinal axis of the two moving body segments. The theoretical joint axis may also shift during ROM (i.e., shifting of the theoretical hip axis during hip abduction) making accurate measurement even more difficult.

The Leighton fleximeter is a commonly used device which eludes the axis' problems. This instrument has a pointer that is weighted on one end to keep it perpendicular to the ground and a weighted 360° dial. The dial is free to move with the body part, thus it rotates while the pointer remains vertical. The Leighton fleximeter is a relatively simple device which is strapped onto the body segment and uses gravity to measure ROM. Reliability coefficients higher than 0.90 have been shown with this instrument (Leighton, 1955; Verducci, 1980).

Range of motion may also be assessed using indirect measurements. All linear measures of ROM are indirect methods. An example of a linear measurement is the sit and reach test which traditionally uses a ruler that

permits measuring ROM in inches or centimeters. The validity of indirect assessment of ROM is questionable due to individual differences in body segment size. Wear (1963) demonstrated that indirect testing may be affected by these differences. However, the American Alliance of Health, Physical Education, Recreation, and Dance has stated that scores on the sit and reach test are largely unaffected by varying leg lengths, arm lengths, and their various ratios (AAHPERD, 1984). Most health-related physical fitness testing batteries now use the sit and reach test as a measure of joint mobility. This test is emphasized because it has been noted in clinical settings that people with low back pain often have a diminished range of motion in the lower back and hamstring muscles (Nieman, 1986). This does not infer causality, only that a relationship may exist.

### **Factors Affecting Flexibility, Range of Motion, and Stretching**

Flexibility and ROM are very complex phenomena. It is not possible to examine the factors influencing flexibility and ROM without also considering those factors which affect stretch. A comprehensive list of these factors follows (Kravitz & Harter, 1990; Sapega, et al., 1981; Wright & Johns, 1960):

1. Anatomical shape of the bones forming the joint,
2. Type and structure of connective tissue at the joint,
3. The presence or absence of inflammation,

4. Age, gender, and physical activity level of the individual,
5. The ability of opposing muscles to relax, degree of muscle tonus,
6. The magnitude and duration of applied stretching force,
7. Tissue temperature, and
8. Spinal reflexes, which facilitate or inhibit muscular function.

The bony structure of a joint, being genetically determined, is largely unalterable. Although the bony structure can potentially limit flexibility and stretching, the limiting factors are generally the soft tissues about the joint (Johns & Wright, 1962; Sapega, *et al.*, 1981; Wright & Johns, 1960). The different contributions of soft tissue which may impose limits on ROM were determined by Johns and Wright (1962): joint capsule 47%, muscle and fascia 41%, ligaments and tendons 10%, and skin 2%. When stretched repeatedly, muscle can be lengthened roughly 20%, while tendons can increase in length only 2 to 3% (Kravitz & Harter, 1990). The muscle and fascial sheath have the most elastic tissue, resistance being primarily from the fascia (Banus & Zetlin, 1938; Ramsey & Street, 1940). Hence, connective tissue (*i.e.*, the fascial sheath) is the target organ of a good flexibility program. Care must be taken not to stretch ligaments or the joint capsule because joint laxity and subsequent injury may occur.

**Inflammation of the joint and associated tissues will negatively affect**



flexibility and ROM. Cryotherapy has been shown to be effective when an injured joint is undergoing a flexibility program. However, for a healthy person cryotherapy would drop tissue temperature, possibly increasing the resistance to stretch (Prentice, 1982; Cornelius & Jackson, 1984).

Aging has been associated with a progressive decline in ROM (Buxton, 1957; Phillips, 1955). Decreased joint mobility is probably a result of disuse and a loss of elasticity in the soft tissues. As people grow older they generally become less active, allowing connective tissue to shorten. People who are active tend to have higher ROM than people who are inactive (McCue 1954). In fact, exercise may improve ROM (Hartley-O'Brien, 1980; deVries, 1962). Some individuals and coaches believe that resistance exercise will negatively affect ROM. Little evidence supports this belief (Todd, 1985). In fact, heavy resistance training may result in either an improvement or no change in ROM status (Massey & Chaudet, 1956). In a descriptive study of several athletic groups, Olympic weight lifters were found to be second only to gymnasts in a composite ROM score (Jensen & Fisher, 1979). In addition to the individual differences of age and physical activity level, gender also influences flexibility and ROM. Generally women tend to be more flexible and have greater ROM than men, at least in adolescence (Phillips, 1955; Kraus & Hirschland, 1954).

Factors such as tissue temperature, bony limitations, type and structure of connective tissue at the joint, inflammation, age, gender, physical activity level of the individual, degree of muscle tonus, and the magnitude and

duration of the applied stretching force affect ROM (Borms & Van Roy, 1987; Etnyre & Lee, 1987; Guissard *et al.*, 1989; Lehmann, Masock, & Warren, 1970; Moffatt, 1988). However, these factors were not studied in this experiment. "Contract-Relax and Agonist Contraction" is a proprioceptive neuromuscular facilitation technique which is based upon the effects on the spinal reflexes. Therefore, all factors other than spinal reflexes were held constant.

### **Spinal Reflexes Affecting Flexibility and ROM**

#### **The Autogenic Stretch Reflex: The Muscle Spindle**

The rapid stretch of a muscle leads to its own reflex contraction. This myotatic reflex (muscle stretch reflex) plays a very important role in the body's postural support (Berne & Levy, 1990). If the legs begin to buckle because of factors such as fatigue and the constant pull of gravity, the extensor muscles are stretched. Their prompt reflexive contraction restores the extension of the limb. The stretch receptors responsible for this reflex are in muscle spindles within the muscles. They are proprioceptors, which provide information about the relationship of parts of the body. The muscle spindles found in skeletal muscle are complex both functionally and structurally. Muscle spindle fibers are sensitive to a change in length as well as the rate of change in length of the muscle fiber (Prentice & Kooima, 1986).

When a muscle is stretched, a distortion of the stretch receptor endings occurs. This is a mechanical stimulus which causes the receptors to generate nerve impulses. The impulses are conducted to the central nervous system, resulting in the excitation of motor neurons to the regular skeletal muscle tissue. This is the "stretch reflex" contraction of the muscle. If a muscle is properly stretched before contraction a greater force will be generated possibly, or in part, because of the stretch reflex (Prentice & Kooima, 1986).

A reflex contraction produced by the stretch itself is supplemented by additional spindle firing: This loop is an example of positive feedback because it is self-augmenting. Signals originating from the muscle cause excitatory impulses to feedback to the muscle through this mechanism, called the gamma loop. Since autogenic (self-generated) is the term used when changes within an organ lead to its own reflex regulation, the reflexive contraction of a muscle in response to its own stretch is an autogenic response.

### **Reciprocal Inhibition**

Muscle contraction will effectively produce movement only if unopposed by contraction, or length limitations, of the antagonistic (or opposite) muscles. Reciprocal inhibition is a mechanism which reduces this problem. It prevents reflexes of opposite action from occurring simultaneously and forces them to alternate. For example, joint flexion is accomplished by flexor muscle contraction while reciprocal inhibition insures relaxation of extensors.

However, reciprocal inhibition can be overridden by strong impulse signals at the motor neurons of these muscles. This can be accomplished voluntarily or with strong reflex contractions. Co-contraction of the arm as in voluntary isometric exercise is a simple example of this phenomenon.

### **Autogenic Inhibition: The Golgi Tendon Organ**

Muscle contraction is not always self-augmenting. Muscle contraction can also be self-limiting, which happens through a negative feedback loop. In this case, different receptors are involved and they lead to motor neuron inhibition rather than excitation. The receptors are called Golgi tendon organs and are located in the tendons, at the junction of the tendon and muscle tissue. The Golgi tendon organs have a higher threshold than the spindles; the muscle spindles may be activated while the Golgi tendon organs are not. In this case, the contraction is augmented by stretch reflex (spindles) and is not opposed by inhibition (Golgi tendon organs). The Golgi tendon organs are actually protective mechanisms. When the tension is high and potentially dangerous (i.e., possible injuring or detaching tendon), the Golgi tendon organs are stimulated. The contracting muscle's motor neurons are inhibited by the reflex action of the tendon organs, thus protecting against possible injury.

Skeletal muscles only have an excitatory motor supply, unlike smooth muscles which generally have dual innervation (both excitatory and inhibitory). In other words, to inhibit skeletal muscle activity the motor neurons supplying

the muscles must be prevented from firing. The muscles themselves are not inhibited, rather they are not excited. The Golgi tendon organs are the sensory organs of a bisynaptic (3-neuron) reflex arc which inhibit the motor neurons. This can alleviate excessive stress on the tendons (and related structures) by limiting the force of muscle contraction (Berne & Levy, 1990).

The Golgi tendon organs are also involved in reciprocal facilitation. While inhibiting contraction of the muscle attached to the tendon they facilitate its antagonist. The afferent fibers of the Golgi tendon organ excite interneurons which lead to the motor neurons of the antagonist similar to reciprocal inhibition. Reciprocal innervation forces opposing reflexes to alternate, preventing simultaneous action.

It should be remembered that the motor neurons of the spinal cord always receive a combination of excitatory and inhibitory impulses from the afferent neurons. The motor neurons can be either excited or inhibited, depending on the ratio of incoming excitatory and inhibitory impulses (Prentice & Kooima, 1986).

### **Proprioceptive Neuromuscular Facilitation**

The basis of Proprioceptive Neuromuscular Facilitation lies in using knowledge of neural reflexes to increase ROM. Sherrington described muscle facilitation and inhibition, the foundation of PNF, in the early 1900's (Sherrington, 1906; Sherrington, 1953). In the mid 1950's Kabat, used

Sherrington's principles to develop Proprioceptive Neuromuscular Facilitation (PNF) for rehabilitation purposes (Holt, Travis, & Okita, 1970). Knott and Voss (1965) expanded the application of PNF to people without paralysis and found the stretching method was very successful (Holt, Travis, & Okita, 1970).

Currently, there is a diverse array of PNF techniques based on the principles of neural reflexes. These protocols have various labels such as Contract-Relax, Hold-Relax, Slow Reversal-Hold-Relax, Antagonist-Contract, Isometric contraction of the Agonist followed by concentric contraction of the Antagonist, Agonist Contract-Relax, Hold Relax-Agonist Contraction, and Contract-Relax and Antagonist Contraction (Condon & Hutton, 1986; Entyre & Lee, 1988; Guissard, Duchateau, & Hainaut, 1989; Osternig & Robertson, 1990; Prentice & Kooima, 1986; Tanigawa, 1972).

When compared to static stretching, PNF protocols generally have been shown to be superior for increasing ROM, although the differences were not always significant (Cornelius & Hinson, 1980; Entyre & Abraham, 1986; Entyre & Lee, 1988; Hardy, 1985; Holt & Smith, 1983; Holt, Travis, & Okita, 1970; Moore & Hutton, 1980; Sady, Wortman, & Blanke, 1982; Tanigawa, 1972).

Holt, Travis, and Okita (1970) conducted a landmark study involving a comparison of three stretching techniques for improving range of motion of hip flexion and knee extension. Twenty-four male college students were randomly assigned to either a fast stretch treatment (ballistic), a slow stretch treatment (static), or a modified version of PNF (similar to CRAC). The mean

improvements for the fast stretch, slow stretch, and modified version of PNF were 6/8 in., 6/8 in., and 2.1 in. respectively. Multiple regression analysis indicated the superiority of the modified PNF stretching technique.

Sady, Wortman, and Blanke (1982) examined the effects of ballistic, static, and PNF stretching techniques on shoulder, trunk, and knee ROM. Sady, *et al.* used sixty-five male college students which were randomly assigned to either a control, ballistic, static, or PNF group. The PNF technique used was contract-relax. The results of the 3-day per week, 6-week flexibility training study showed that only the PNF method had ROM increases (10.6 degree increase) greater than the control group (3.4 degree increase).

The effects of the slow-reversal-hold PNF technique on hip flexion was examined by Prentice in 1983. Forty-six subjects, both male and female, were randomly assigned to one of two treatment groups, static stretching group or the PNF group. The subject's right leg was used as the experimental while the left leg served as the control. The subjects underwent the stretching protocol 3 days per week for 10 weeks. The results of this study showed that both static and slow-reversal-hold stretching methods increased hip flexion ROM during the training period. However, the PNF technique of slow-reversal-hold was superior to the static stretching technique, supporting Holt *et al* and Sady *et al.*

Lucas and Koslow (1984) examined the effects of three stretching methods on 63 college women. Ballistic, static, and a variation of CRAC were used as the stretching protocols, each performed 3 times per week for a total

of 10 weeks. The results of an ANOVA showed that all three methods significantly increased ROM; There was no significant difference between treatments.

Etnyre and Abraham (1986) conducted a study which was very similar to Condon and Hutton (1986) in which static stretching was compared with PNF stretching (using the soleus). While Condon and Hutton concentrated on the EMG activity of the soleus, Etnyre and Abraham were solely concerned with the effects of stretching methods on plantar flexion ROM. The subjects, twelve college-age males, performed each of the three techniques (static, contract-relax, or contract-relax with agonist contraction), one per day for three days. The results showed significant increases in ROM for the CR and the CRAC, but not for the static stretching method. Furthermore, the CRAC method was superior to the CR method for increasing ROM.

In 1986, Hardy and Jones examined the immediate and long-term effects of dynamic (ballistic) and PNF stretching methods on shoulder extension and hip flexion ROM. The PNF technique used was a variation of CRAC. The results showed that ballistic and PNF methods were equally effective for increasing ROM for shoulder extension and hip flexion.

Condon and Hutton (1986) compared static stretching against three different PNF techniques, hold relax (HR), agonist contraction (AC), and hold relax-agonist contraction (HR-AC). Although the main emphasis of their study was the presence, or absence, of EMG activity during different stretching



methods, the efficacy of these stretching methods was also noted. Six men and six women were subjected to each of the four different protocols designed to lengthen the soleus (increasing ankle dorsiflexion). The results showed that stretching procedures (and their order) had no significant effect on the degree of ankle dorsiflexion achieved.

Although most studies prior to 1988 suggested that PNF techniques were superior to static stretching techniques, it still was unclear if one PNF protocol was superior to another (ie., CR versus CRAC). To address this question, Etnyre and Lee conducted a comparison study of static, CR, and CRAC stretching methods on shoulder extension and hip flexion ROM. Seventy-four college age subjects (49 men and 25 women) participated in the 12-week study. The results showed CR and CRAC significantly increased shoulder extension and hip flexion ROM, while the static method showed no improvement. The women benefited equally from CR and CRAC, while the men showed larger gains with CRAC. These findings contradicted Condon and Hutton (1986), who found no significant gains in ROM from PNF stretching methods.

Because of the contradictions in the literature, it is clear that more studies dealing with the efficacy of different stretching techniques are needed. The goal of this study is to add vital information to the current database of knowledge.

## **CHAPTER 3**

### **METHODS**

#### **Research Design**

A pretest - posttest control group quasi-experimental research design was used to examine the immediate effects of "Contract-Relax and Agonist Contraction" on active and passive hip abduction ROM. The twenty-four subjects were randomly assigned to either the experimental group (n=12) or to the control group (n=12).

#### **Subjects**

Twenty-four female volunteers from the University of Montana were recruited during Summer Session 1990 to participate in the study. Physical characteristics of the subjects are presented in Table 1. An ANOVA revealed no significant differences between the experimental and control groups in age, height or mass. The subjects met the following criteria:

1. Female, 18 - 35 years of age,
2. Not presently engaged in a stretching program,
3. No lower extremity injuries or conditions for which moderate stretching may be contraindicated.

**Table 1. Descriptive data of experimental (n=12) and control (n=12) group subjects**

<b>Subject Characteristics</b>	<b>Mean</b>	<b>SD</b>	<b>Range</b>
<b>Age (yrs)</b>			
Experimental	24.92	3.92	21.00-31.00
Control	23.58	3.63	18.00-30.00
<b>Height (cm)</b>			
Experimental	165.10	5.55	157.48-175.26
Control	166.16	6.54	157.48-180.34
<b>Mass (kg)</b>			
Experimental	60.87	4.42	54.55-68.19
Control	59.55	5.90	50.00-68.12

## **Instrumentation**

### **Stretching Device**

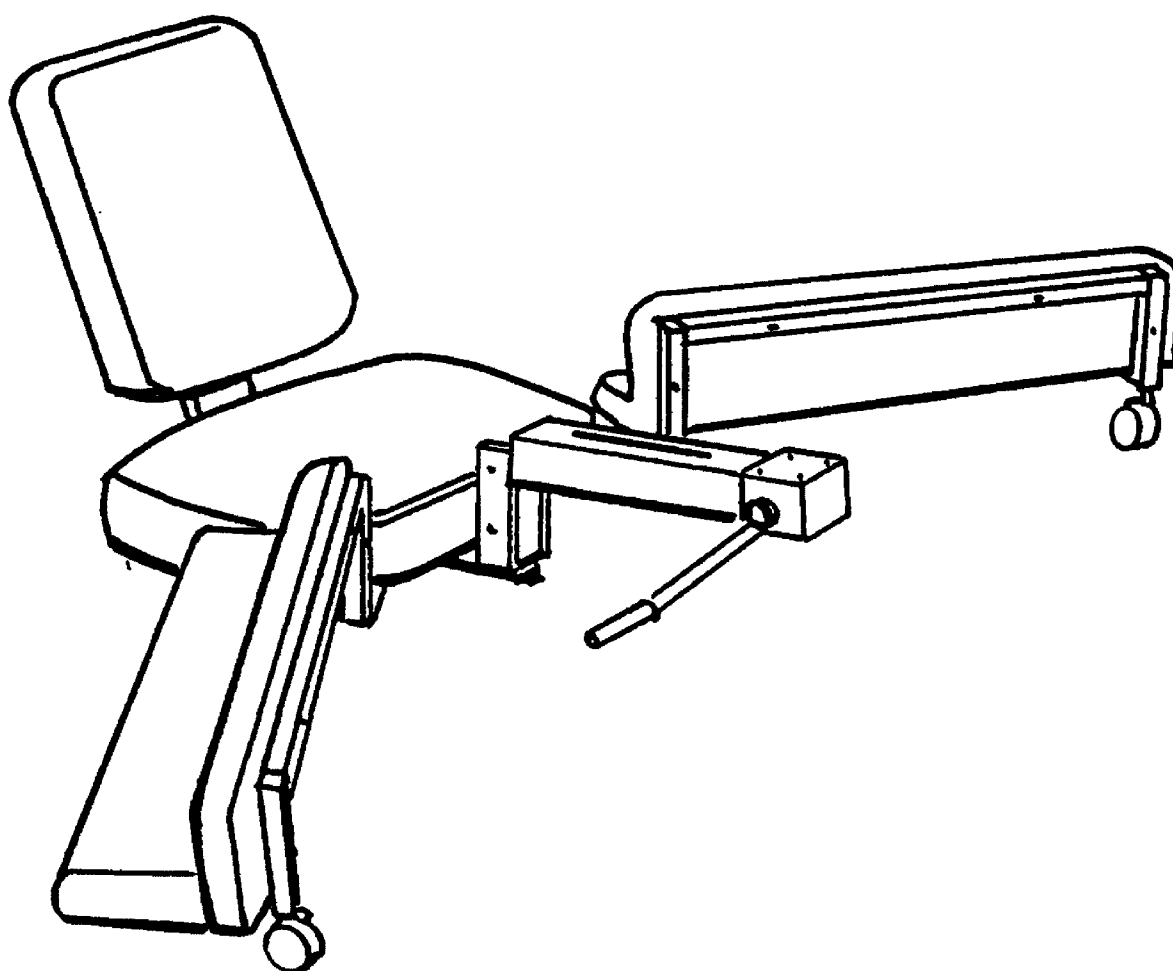
The stretching apparatus was a Powerstretcher by Treco (Figure 1). The Powerstretcher is a chair-like device in which the subject sat, assuming a straddle position with one leg on either side of the Powerstretcher's "arms." A crank was positioned in front of the subject. Depending on which way the crank was turned, the subject's lower limbs would either be abducted or allowed to adduct. In this manner the adductors of the leg could be effectively lengthened in a controlled and measurable environment. When external resistance was applied to the legs (by the stretcher) the "straddle" test was used to measure passive ROM of the adductor magnus, adductor longus, adductor brevis, pectineus, gracilis, and to a lesser extent the hamstring muscle group. A measurement of the angle, in degrees, was displayed by the Powerstretcher (see Figure 1).

### **Camera**

To measure the angle of hip abduction, a 35 mm motor driven single-lens reflex still camera was used to photograph the subject's limbs. A model T70 from Canon (One Canon Plaza, Lake Success, NY 10016) was used. The camera was mounted on a wooden support positioned 3 meters above and perpendicular to the floor, with the Powerstretcher (and subject) centered in

the camera's field of vision (Figure 2). Each film exposure was triggered by an electronic switch mounted in easy reach of the investigator.

Figure 1. "Power Stretcher" by Treco



### **Electromyography**

Surface electromyography (EMG) was used to monitor the electrical activity of the adductor muscle groups. This was used, along with verbalization of maximal length by the subject, as a criterion for maximal muscle length (maximal stretch). This ensured there was no active contraction (of the muscles being stretched) during the stretch. A model GCS from Therapeutics Unlimited (2535 Friendship Street, Iowa City, Iowa 52240) was used.

## **Procedures**

### **Subject Preparation**

Volunteers participated in an information and training session during the week of June 25 - June 30, 1990. During this session, the purpose of the study was explained. All procedures of the study were also explained and demonstrated. Each subject actively participated in learning the measurement procedures and the PNF stretching protocol. Also, after this session, the subjects thoroughly understood and appreciated the potential minimal risks involved. After the subjects received the answers to their questions, they signed an Informed Consent Form that was approved by the Institutional Review Board for the Use of Human Subjects in Research at the University of Montana (Appendix A). They also completed a brief Medical History (Appendix B). At this time the subjects were scheduled for their testing sessions (which were within two weeks of the initial information and training

sessions). The subjects were instructed to avoid strenuous lower body workouts for three days prior to testing. This precaution, as with randomized testing order, was to minimize the influence of extraneous variables.

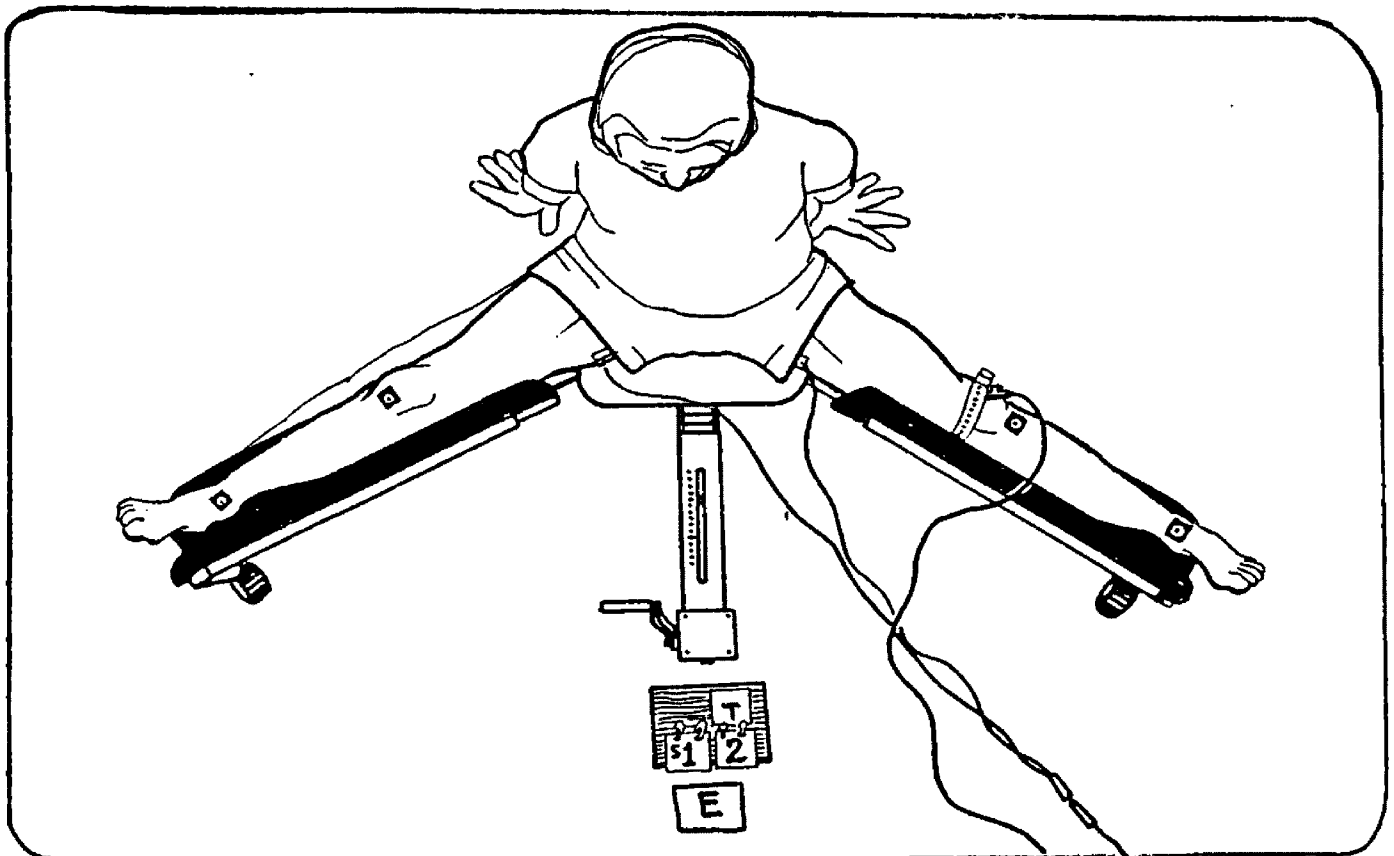
### **Subject Testing**

Active and passive ROM were measured during both the pretest and posttest with 30 seconds between measurements. Anatomical landmarks on the lower extremities were marked using tape to approximate the longitudinal axis of the lower extremity. The tibial tuberosity and the midpoint between the medial and lateral malleolus on the ankle were used for landmarks. When the subject achieved maximal active or passive abduction, a still picture was taken perpendicular to the subject's legs (see Figure 2). Active ROM was determined by each subject's ability to abduct her limbs using her own musculature as the force (agonists). Passive ROM was determined by using the Powerstretcher to maximally lengthen the musculotendinous structures. Maximal abduction was determined by two criteria: 1) lack of EMG activity and/or 2) verbalization by the subject that maximal abduction was reached.

The subjects in the experimental group were pretested using measurements of active ROM and passive ROM. After 1 min. 30 sec. rest, they proceeded with the PNF protocol. After finishing PNF, each subject rested another 1 min. 30 sec., then was posttested using the same active ROM and passive ROM measurement procedures utilized in the pretest. The two

measurements, active and passive ROM, were randomized in terms of order, thus controlling for systematic errors. There were also 30 seconds between measurements to standardize procedures. This was true for both pretest and posttest measurements. Furthermore, the control group rested for 4 minutes, 15 seconds between pretest and posttest measurements (the duration of testing for the experimental group).

Figure 2. Camera's Field of View





The specific PNF technique used was the "contract-relax and agonist contraction" method (CRAC) (Knott & Voss 1965). The legs were passively abducted by the Powerstretchers to the point of discomfort. At this point the investigator instructed the subject to "squeeze" her legs inward against the resistance of the Powerstretchers by isometrically contracting the antagonist adductors. This contraction was met with equal resistance from the Powerstretchers, thus maintaining the original joint angle. This phase lasted for 5 seconds. Immediately afterward the subject was instructed to abduct her legs strongly, but submaximally, thus employing the agonist muscle groups. The contraction was submaximal to prevent the already shortened musculature from cramping. During this phase, which lasted 5 seconds, the adductors were relaxed while the agonist muscle groups were contracted, thus stretching the antagonist further. A 30 second period of complete relaxation followed, after which the subject used the Powerstretchers to abduct further. A photograph was then taken of the "new" passive ROM position. The sequence of squeezing the legs together (5 sec.), attempting to pull the legs further outward (5 sec.), rest (30 sec.), and photographing the new passive ROM achieved, was repeated 3 times. The experimental group underwent the stretching protocol for 4 minutes and 15 seconds. The control group rested for the equivalent amount of time between pretest and posttest measurements (4 minutes, 15 seconds).

### **Data Reduction and Statistical Analysis**

After the film (from testing) was developed into 4"x6" prints, ROM was assessed by using a protractor to measure limb angle (aligning tape markings). Descriptive statistics were used to depict the measures of central tendency and the measures of variability. Since the data were ratio level and there were two groups (PNF & control), an ANOVA for repeated measures was used to examine the differences between groups (control and experimental) and among stretching conditions. An ANOVA within groups was used to examine the pretest and the post test measures within each group. Intraclass Correlation Coefficients (ICC) (Bartko, 1966) were conducted on the active and passive tests and retests within the control group to examine the reliability of the measurements. The 0.05 level of significance was used for all computations. All data were analyzed with SYSTAT statistics software (SYSTAT Inc., IL, USA) and a microcomputer.

## **CHAPTER 4**

### **RESULTS**

Seven subjects demonstrated EMG activity at the end point of motion, thus defining their maximal hip abduction ROM. Of the experimental group, two subjects showed EMG activity at the end point for the posttest passive ROM tests. Of the control group, three subjects demonstrated EMG activity at the endpoint for the pretest passive ROM tests and three showed EMG activity at the endpoint for the posttest passive ROM tests. Two control group subjects showed EMG activity for both pretest and posttest passive tests. All other subjects lacked EMG activity at the endpoint. Verbalization of maximal stretch was the criterion for defining the end point in these subjects. It was observed that subjects only exhibited EMG activity at the endpoint of passive ROM tests and not at the endpoint of active ROM tests. No other obvious patterns were observed with regard to EMG activity in subjects.

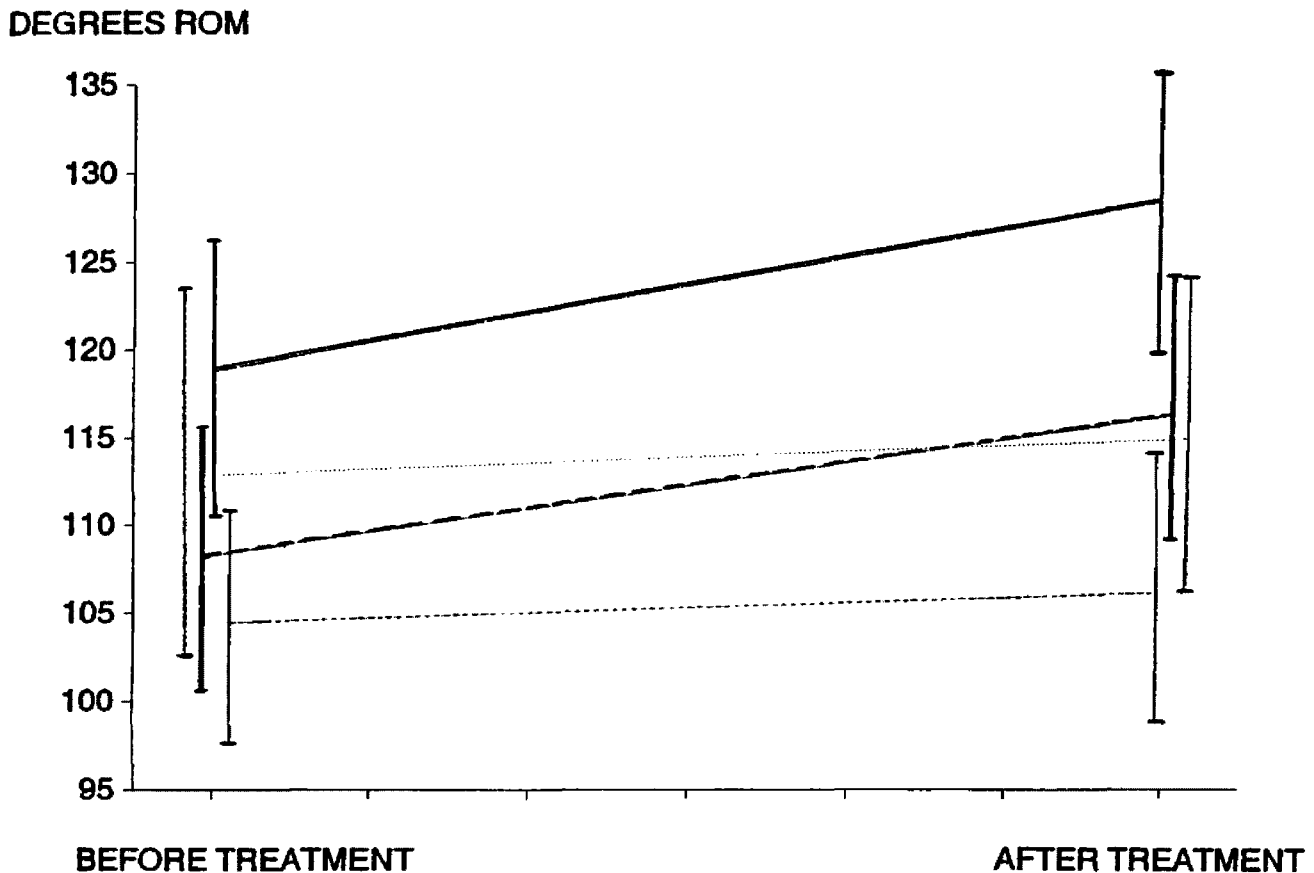
The correlation coefficients for the active and passive test and retest measurements were  $ICC=0.97$  and  $ICC=0.99$ , respectively, indicating very good reliability. Descriptive statistics of the maximal passive and active hip abduction ROM are reported in Table 2. Results of the ANOVA showed no significant group difference for pretest passive ROM, pretest active ROM,

posttest passive ROM, or posttest active ROM, however, results of the ANOVA indicated a significant interaction between groups when considering ROM measurements (pretest and posttest) ( $F=2.82$ ,  $P<0.05$ ) (see Figure 3). An ANOVA within groups revealed significant differences between experimental pretest and posttest passive ROM ( $F=80.27$ ,  $P<0.01$ ), and experimental pretest and posttest active ROM ( $F=9.66$ ,  $P<0.05$ ). The control group showed no significant difference for pretest and posttest active ROM, but did show a significant difference between pretest and posttest passive ROM ( $F=12.21$ ,  $P<0.01$ ).

**Table 2. Descriptive statistics for experimental group (n=12) and control group (n=12) for the "CRAC" results**

<b>Measurements</b>	<b>Mean</b>	<b>SD</b>	<b>Range</b>
<b>Pretest - Absolute Passive ROM (degrees)</b>			
Experimental	118.83	16.12	82.50-145.00
Control	112.88	20.53	94.50-169.00
<b>Pretest - Absolute Active ROM (degrees)</b>			
Experimental	108.33	15.14	85.00-133.00
Control	104.42	13.63	88.00-131.00
<b>Post test - Absolute Passive ROM (degrees)</b>			
Experimental	128.50	17.27	87.00-154.00
Control	114.96	19.52	96.50-168.00
<b>Post test - Absolute Active ROM (degrees)</b>			
Experimental	116.29	16.47	80.00-149.50
Control	106.21	15.15	90.00-136.00

**Figure 3. Immediate Effects of "Contract-Relax with Agonist Contraction" on Active and Passive Hip Abduction Range of Motion**



**LEGEND**

————	Experimental Passive	118.83 (SD 16.12) - 128.50 (SD 17.27)
-----	Experimental Active	108.30 (SD 15.14) - 116.29 (SD 16.45)
.....	Control Passive	112.88 (SD 20.53) - 114.96 (SD 19.52)
- - - - -	Control Active	104.42 (SD 13.63) - 106.21 (SD 15.15)

## **CHAPTER 5**

### **DISCUSSION**

The Experimental group, which used the PNF protocol "Contract-Relax and Agonist Contraction" did not differ significantly from the control group in this study. These results, which support the null hypothesis, may have resulted from a Type II error. A Type II error is made when the null hypothesis is accepted when it is actually false. Of course, Type II error potentially exists in all scientific examinations of hypotheses. However, several factors may have increased the probability of Type II error in this study, including sample size, sample variability, and the power of the statistics used. If 100 subjects instead of 24 had been used, the power of the statistics would have been much greater, perhaps enough to yield significant differences between the experimental and control groups. The variability between subjects was also great (S.D. for control pretest passive = 20.53 degrees), which lessened the power of the statistics. This variability could have possibly been reduced by either selecting a more homogeneous group, a larger sample size, or both. Again, if the variation between subjects had been reduced, the study may have demonstrated significant differences between the experimental and control groups.

Factors other than potentially committing a Type II error may have contributed to the results. For example, the duration of contractions may not have been optimal for increasing ROM. Future research should investigate the time of contractions, possibly comparing 5 second contractions with the effects of 10 second contractions, or even 15 second contractions. Or perhaps this study did not allow enough time for results to show. Six "cycles" of the CRAC protocol might be shown to be effective whereas using three (in this study) has been shown to be ineffective.

Even though no significant differences between groups were found, a significant interaction was found. The experimental group displayed a higher mean ROM after the PNF protocol (compared to the control group). This phenomenon was observed for both passive and active ROM measurements and was consistent with the findings of related investigations. Other investigations have shown similar increases in mean ROM (attributed to PNF stretching); however, the differences were usually great enough to be statistically significant. The majority of related studies, examining primarily two-joint muscle ROM, reported gains in ROM for subjects who underwent a PNF stretching protocol (Cornelius & Hinson, 1980; Hartley-O'Brien, 1980; Holt & Smith, 1983; Holt *et al.*, 1970; Lucas & Koslow, 1984; Moore & Hutton, 1980; Sady *et al.*, 1982; Tanigawa, 1972). Of the six studies which included the CRAC protocol, two found CRAC to be equal to either the static stretch (SS) or contract-relax (CR) methods (Lucas & Koslow, 1984; Hartley-



O'Brien, 1980). Cornelius & Hinson (1980), Holt & Smith (1983), Holt *et al.* (1970), and Moore & Hutton (1980) found the CRAC method to be not only effective for increasing ROM, but superior to either static stretching or to contract-relax stretching. Even though studies prior to 1986 supported the efficacy of CRAC, they examined only joints limited primarily by two-joint muscles. In 1986, Entyre and Abraham examined the effect of stretching methods on a one-joint muscle (bent-knee ankle dorsiflexion limited primarily by the soleus). Entyre and Abraham (1986) found the CRAC method to be superior to CR, which in turn was superior to SS. Significant gains in ROM were observed for the CRAC and CR, but not for SS. Entyre and Abraham's investigation of the effect of CRAC on one-joint muscles supported the previous findings about two-joint muscles. In 1986, Condon & Hutton verified that PNF stretching (and static stretching) was effective: however, they found an interesting difference between genders. Within the parameters of their study, Condon & Hutton reported that women had smaller gains in range of motion than men. Because of inconsistencies in the literature regarding the most effective method of stretching, Entyre and Lee (1988) conducted additional research in the area. Entyre and Lee compared the effects of three commonly used methods of stretching, SS, CR, and CRAC, on both men and women. The results showed SS to be the least effective method (women decreased ROM and men increased ROM only slightly). Both PNF methods increased ROM significantly. The men had greater gains using CRAC, while

the women attained similar ROM with either CRAC or CR. Etnyre and Lee (1988) hypothesized that the difference between sexes may be partially due to the women's greater overall ROM which may facilitate stretch-related activation of the muscles at the extremes of ROM.

The investigators dealing with PNF stretching methods have attributed increases in ROM to the theoretical neurological effects of PNF. These methods allegedly increase ROM through relaxation (decreased contraction) of the muscle being stretched. Three mechanisms postulated to affect muscle relaxation are as follows: 1) stretch reflex 2) autogenic inhibition, and 3) reciprocal inhibition. The stretch reflex is an autogenic contraction of the muscle being stretched. The muscle spindles, proprioceptors responsible for the stretch reflex, are sensitive to the change in length as well as the rate of change of length. This reflex contraction, though important for postural support, may negatively influence ROM. Proprioceptive neuromuscular facilitation stretching methods (i.e., CRAC and CR) are slow and relatively prolonged stretches aimed at reducing the "stretch reflex." (In this regard, PNF stretching is similar to static stretching.)

Proprioceptive neuromuscular facilitation stretching methods (i.e. CRAC and CR) also rely on autogenic inhibition, which is the self-limiting inhibition of motor neurons by the Golgi tendon organs. The Golgi tendon organs, located in the tendons, are sensitive to tension. When the tension is high, the Golgi tendon organs are stimulated, thus relaxing the muscle to which the

tendon is attached. The CRAC protocol used in this study sought to evoke autogenic inhibition through contracting the adductors near-maximally.

Producing reciprocal inhibition, in addition to autogenic inhibition and the reduction of stretch reflex, is the rationale of CRAC (CR does not rely on this mechanism). Reciprocal inhibition deters reflexes of opposite action from occurring simultaneously, forcing them to alternate. In theory, submaximally contracting the hip abduction musculature should inhibit the contraction of adductor musculature, promoting relaxation of the muscle being stretched. Reciprocal inhibition may account for the reported superiority of CRAC over other PNF methods (i.e., CR) and over SS (Cornelius & Hinson, 1980; Entyre & Abraham, 1986; Entyre & Lee, 1988; Holt & Smith, 1983; Holt *et al.*, 1970; Moore & Hutton, 1980). It may also be partially responsible for the increased mean hip abduction ROM observed in this study.

Also observed in this study was the tendency of passive ROM to be greater than active ROM. For example, the experimental mean passive ROM for the pretest was 118.8° while the active was only 108.3°. The experimental mean passive ROM for the posttest was 128.5° while the active was only 116.3°. The control group showed similar tendencies (pretest passive ROM was 112.9° vs. pretest active ROM of 104.4°; posttest passive ROM was 115.0° vs. posttest active ROM of 106.2°). Common sense indicates that it is possible to apply more abduction force externally (i.e., using the PowerStretcher), than is possible using internal force (using one's own musculature). When the limiting

factor is the musculature, a greater force should lead to greater ROM. This would seem to be true for the muscles involved in hip abduction, and most two joint muscles, like the hamstring musculature. If ROM is restricted by bony limitations, then a greater force, whether external or internal, will most likely not lead to greater ROM (without imposing undue stress upon the joint capsule). More research is needed with regard to active ROM. Of the research to date, only two investigations (Hartley-O'Brian, 1980; Hardy, 1986) have specifically examined active ROM. Hartley-O'Brian showed no significant results among seven PNF stretching protocols. They all showed increases of 15 degrees or more; However, the control group also showed increases of 15 degrees or more. Hardy (1986) compared the effects of seven treatments (two ballistic stretching methods, one PNF method). The results showed a significant increase of ROM for both ballistic groups and for the PNF group. No one stretching method was shown to be superior.

In this experiment, seven subjects demonstrated EMG at the endpoint of passive range of motion while none demonstrated EMG activity at the endpoint of active ROM. This phenomenon may be due to several factors. During active ROM testing the subject contracted the abductor musculature which theoretically lead to inhibition of the opposing muscle group (the adductors). Since the adductors were the muscle group monitored for EMG activity, reciprocal inhibition would account for the decreased level of EMG activity at the endpoint of active ROM tests as opposed to the passive ROM

tests. During the passive ROM tests, reciprocal inhibition would not be invoked.

Noted earlier was the observed tendency of passive ROM to be greater than active ROM. Increased EMG activity at the endpoint of passive ROM tests may be because the subject was abducted farther than while testing for active ROM. The passive ROM tests more closely approached the physiological ROM limits, possibly invoked the muscle spindles, leading to a stretch reflex activation of the hip adductor muscles.

## **CHAPTER 6**

### **SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

#### **Summary**

The purpose of this study was to examine the efficacy of using the PNF protocol, "Contract-Relax and Agonist Contraction", to induce maximal hip abduction ROM. The subjects were 24 healthy women, between the ages of 18 and 35. A quasi-experimental research design was used, with the subjects randomly assigned to either the control group or the experimental group. The experimental group underwent the CRAC protocol, which consisted of contracting the adductor musculature isometrically against an external resistance (the Treco PowerStretcher), then contracting the abductor musculature (agonist) in an attempt to abduct further. The lower limbs were marked with tape and pictures were taken from a camera mounted above. These pictures were developed and the markings measured with a protractor to attain the degrees of ROM. The results were analyzed using an ANOVA for repeated measures ( $p < 0.05$  was used for all statistical computations).

## **Conclusions**

Based upon the analysis of the data collected from this sample of 24 healthy women, and within the limits of this study, the null hypothesis was accepted. The results showed that, although the passive and active ROM increased for the experimental group compared to the control group, there were no statistically significant differences between the experimental and control groups. The ANOVA showed a significant interaction ( $p < 0.05$ ), supporting the observed increased ROM for the experimental group. Additional research is needed to clarify the immediate effects and long term effects of the CRAC protocol for increasing hip abduction ROM.

## **Recommendations**

The following suggestions are offered by the researcher to aid further related studies:

- 1) The research should involve a larger sample of healthy women.
- 2) The research should involve a more homogeneous sample with decreased hip abduction ROM.
- 3) To establish a broad data base of knowledge, additional samples should be used from varying populations, such as men, elite athletes, inactive populations, and senior populations.
- 4) To establish a broad data base of knowledge, additional protocols should be examined and compared. For example, the duration and

intervals of the "Contract-Relax and Agonist Contraction" can be altered to find the optimal protocol for achieving ROM. Likewise, the "Contract-Relax and Agonist Contraction" should be compared to other PNF protocols (i.e. Hold-Relax) to determine the most efficient protocol for inducing maximal ROM.

5) Further research is needed to examine the long term effects of an extended program of PNF stretching.



## **REFERENCES**

- American Alliance of Health, Physical Education, Recreation, and Dance.  
(1984). Technical Manual: Health-Related Physical Fitness. Reston,  
VA.
- Banus, M., & Zetlin A. (1938). The relation of isometric tension to length  
in skeletal muscle. Journal of Cellular Physiology, 12, 403.
- Bartko, J. (1966). The intraclass correlation coefficient as a measure of  
reliability. Psychological Reports, 19:3-11.
- Berne, R.M., & Levy, M.N. (1990). Principles of Physiology. St. Louis: C.V.  
Mosby.
- Borms, J., & Van Roy, P. (1987). Optimal duration of static stretching  
exercises for improvement of coxo-femoral flexibility. Journal of Sports  
Sciences, 39-47.
- Buxton, D. (1957). Extension of the Kraus-Weber test. Research Quarterly  
of Exercise and Sport, 29, 210.
- Condon, S.A., & Hutton, R.S. (1986). Soleus muscle electromyographic  
activity and ankle dorsiflexion range of motion during four stretching  
procedures. Physical Therapy, 67, 24-30.
- Cornelius, W.L., & Hinson, M.M. (1980). The relationship between isometric  
contractions of hip extensors and subsequent flexibility in males.  
Journal of Sports Medicine and Physical Fitness, 20, 75-80.
- Cornelius, W.L., & Jackson, A. (1984). The effects of cryotherapy and PNF  
on hip extensor flexibility. Athletic Training, 26-31.
- deVries, H.A. (1962). Evaluation of static stretching procedures for  
improvement of flexibility. Research Quarterly, 33, 222-229.
- Etnyre, B.R., & Lee, E.J. (1987). Comments on proprioceptive neuromuscular  
facilitation. Research Quarterly for Exercise and Sport, 58, 184-188.

- Etnyre, B.R., & Lee, E.J. (1988). Chronic and acute flexibility of men and women using three different stretching techniques. Research Quarterly For Exercise and Sport, 59, 222-228.
- Etnyre, B.R., & Abraham, L.D. (1986). Gains in range of ankle dorsiflexion using three popular stretching techniques. American Journal of Physical Medicine, 65(4), 189-197.
- Gajdosik, R.L., & Bohannon, R.W., (1987). Clinical measurement of range of motion. Physical Therapy, 67(12), 1867-1872.
- Gajdosik, R.L., Giuliani, C.A., & Bohannon, P.T. (1990). Passive compliance and length of the hamstring muscles of healthy men and women. Clinical Biomechanics, 5, 23-29.
- Godges, J.L., MacRae, H. (1989). The effects of two stretching procedures on hip range of motion and gait economy. The Journal of Orthopaedic and Sports Physical Therapy, 350-356.
- Guissard, N.J., Duchateau, L., Hainaut, K. (1989). Decrease of motoneuron excitability during stretching of the human soleus. Biomed. Biochim. Acta, 5, 489-492.
- Hardy, L. (1985). Improving active range of hip flexion. Research Quarterly of American Association of Health and Physical Education, 56, 111-114.
- Hartley-O'Brien, S.J. (1980). Six mobilization exercises for active range of hip flexion. Research Quarterly, 51, 625-635.
- Henricson, A.S., Fredriksson, K., Persson, I. (1984). The effect of heat and stretching on the range of hip motion. The Journal of Orthopaedic and Sports Physical Therapy, 6(2), 110-115.
- Holt, L., Travis, T., & Okita, T. (1970). Comparative study of three stretching techniques. Perceptual and Motor Skills, 31, 622-616.
- Holt, L.E., & Smith, R. (1983). Effects of three stretching methods on increased range of motion. Research Center for Sport. Del Mar, California.
- Jensen, C., & Fisher, G. (1979). Scientific basis of athletic conditioning. Philadelphia: Lea & Febiger.

- Johns, R. & Wright, V. (1962). Relative importance of various tissue in joint stiffness. Journal of Applied Physiology, 17, 824.
- Knott, M., & Voss, D.E. (1965). Proprioceptive neuromuscular facilitation, patterns, and techniques. New York: Hoeber and Harper.
- Kraus, H., & Hirschland, R. (1954). Minimum muscular fitness tests in school children. Research Quarterly in Exercise and Sport, 25, 178.
- Kravitz, L., & Harter, R. (1990, May). Static and PNF Stretches. Idea Today, 8(3), pp. 70-72.
- Lehmann, J., Masock, A., & Warren, C. (1970). Effect of therapeutic temperatures on tendon extensibility. Archives of Physical Medicine and Rehabilitation, 51, 481.
- Leighton, J. (1955). An instrument and technique for the measurement of range of joint motion. Archives of Physical Medicine & Rehabilitation, 36, 571.
- Lucas, R.C., & Koslow, R. (1984). Comparative study of static, dynamic, and proprioceptive neuromuscular facilitation stretching techniques on flexibility. Perceptual Motor Skills, 58, 615-618.
- Marshall, J.L., Johanson, N., Wickiewicz, T.L. (1980). Joint looseness: A function of the person and the joint. Medicine and Science in Sports and Exercise, 12, 189-194.
- Massey, B.H., & Chaudet, N.L. (1956). Effects of heavy resistance exercise on range of joint movement in young male adults. Research Quarterly, 27, 41-51.
- McCue, B. (1953). Flexibility of college women. Research Quarterly in Exercise and Sport, 24, 316.
- Moffatt, R.J. (1988). Strength and Flexibility Considerations for Exercise Prescription. In Blair, S., Painter, P., Pate, R. et al (Eds.), Resource Manual for Guidelines for Exercise Testing and Prescription (pp. 263-270). Philadelphia: Lea & Febiger.
- Moore, M.A., & Hutton, R.S. (1980). Electromyographic investigation of muscle stretching techniques. Medicine and Science in Sports and Exercise, 12, 322-329.

- Nieman, D.C. (1986). The Sports Medicine Fitness Course. Palo Alto, CA: Bull Publishing Company.
- Osternig, L.R., & Robertson, R.N. (1990). Differential responses to proprioceptive neuromuscular facilitation (PNF) stretch techniques. Medicine and Science in Sports and Exercise, 22(1), 106-111.
- Phillips, M. (1955). Analysis of results from the Kraus-Weber test of minimum muscular fitness in children. Research in Exercise and Sport, 26, 314.
- Prentice, W.E. (1982). An electromyographic analysis of the effectiveness of heat or cold and stretching for inducing relaxation in injured muscle. The Journal of Orthopaedic and Sports Physical Therapy.
- Prentice, W.E. (1983). A comparison of static stretching and PNF stretching for improving hip joint flexibility. Athletic Training, 56-59.
- Prentice, W.E., & Kooima, E.F. (1986). The use of proprioceptive neuromuscular facilitation techniques in the rehabilitation of sport-related injury. Athletic Training, 26-31.
- Ramsey, R., & Street, S. (1940). The isometric length tension diagram of isolated skeletal muscle fibers of the frog. Journal of Cellular Physiology, 15, 11.
- Sady, S.P., Wortman, M., & Blanke, D. (1982). Flexibility training: Ballistic, static or proprioceptive neuromuscular facilitation? Archives of Physical Medicine & Rehabilitation, 63, 261-263.
- Sapega, A.A., Quendenfeld, T.C., Moyer, R.A. (1981) Biophysical factors range-of-motion exercise. Physician and Sportsmedicine, 9(12), 57-65.
- Schultz, P. (1979). Flexibility: day of static stretch. Physician and Sportsmedicine, 7, 109-117.
- Sherrington, C. S. (1906). The Integrative Action of the Nervous System. Yale University, New Haven, England: Yale University Press.
- Sherrington, C. S. (1953). Man on his Nature. Cambridge, Great Britain: Cambridge University Press.

- Tanigawa, M.C. (1972). Comparison of hold-relax procedure and passive mobilization on increasing muscle length. Physical Therapy, 52, 725-735.
- Todd, T. (1985). Historical perspective: The myth of the muscle-bound lifter. National Strength and Conditioning Association Journal, 7, 37-41.
- Verducci, F. (1980). Measurement Concepts in Physical Education. St. Louis: C.V. Mosby.
- Warren, C., Lehmann, J., & Koblanski, J. (1971). Elongation of rat tail tendon: Effect of load and temperature. Archives of Physical Medicine & Rehabilitation, 52, 465.
- Warren C., Lehmann, J., Koblanski, J. (1976). Heat and stretch procedures: An evaluation using rat tail tendon. Archives of Physical Medicine & Rehabilitation, 57, 122.
- Wear, C. (1963). Relationships of flexibility measurements to length of body segments. Research Quarterly Exercise Sport, 34, 234.
- Wright V., & Johns, R. (1960). Physical factors concerned with the stiffness of normal and diseased joints. Bulletin Johns Hopkins Hospital, 106, 215.

**APPENDIX A**  
**INFORMED CONSENT FORM**

## INFORMED CONSENT

**Project Title:** Immediate effects of "contract-relax and agonist contraction" on active and passive hip abduction range of motion

**Investigator:** Shawn O. Henry (W) 243-5528 (H) 542-1614

**Co-Investigator:** Richard Gajdosik, Ph.D. (W) 243-4753

I understand that I am participating in the research project titled above. This project is designed to study the effects of a type of stretching (Proprioceptive Neuromuscular Facilitation, or PNF) on the degree of hip abduction possible, both actively and passively. The degree of hip abduction possible will be measured while sitting in a "chair-like" device (legs are straight) and abducting the legs outward in a straddle position. I understand that 24 normal healthy adult women (18-35 yrs) will participate in this research project.

I understand that my age, weight, and height will be recorded and only used for research purposes. I will not be identified in the research project.

I agree to wear shorts or a bathing suit so that the skin of lower limbs can be marked with tape to identify landmarks of the lower extremity.

I understand I will be in a seated position with my legs straight and abducted (straddled) in order to measure the degrees of ROM of hip abduction. I have participated in a practice testing procedure and I know how I will be positioned, stabilized, and tested. I also know and understand the PNF stretching protocol that will be performed by the experimental group.

I understand that surface electromyography will be used to monitor adductor (inner thigh) muscle group activity.

I understand that photographs will be taken to document ROM: 1) pretest active ROM 2) pretest passive ROM 3) posttest active ROM 4) posttest passive ROM.

I understand that I will not be identified in the photographs.

I understand that although every precaution will be taken to insure my comfort and safety, some mild discomfort and soreness may occur from the stretching protocol and the passive extension of the adductor muscles. The mild "stiffness and soreness" is not unlike that experienced after an exercise session (i.e. weight training).

I understand that hip ROM testing will require 1 session of 30 minutes or less.

I understand that my questions about the research project (i.e. methods, procedures, outcomes, relevance, etc.) are encouraged so that I may fully understand the research project and its implications.

I understand that Shawn O. Henry (542-1614) is responsible for my welfare during the experiment.

I understand that all subjects will be interviewed to screen for neurologic and orthopedic problems before testing.

I understand that as a subject participating voluntarily, I am free to withdraw from this study at any time of my choosing. Confidentiality will be maintained in any published material, as well as in the data analysis.

I understand that "In the event physical injury results from biomechanical or behavioral research the human subject should individually seek appropriate medical treatment and shall be entitled to reimbursement or compensation consistent with the self insurance program for Comprehensive General Liability established by the Department of Administration under authority of MCA Title 2, Chapter 9 or by satisfaction of the claim or judgement by a means provided by MCA, Section 2 - 9 - 315. In the event of a claim for such physical injury, further information may be obtained from the University Legal Counsel."

I have read the above statements, and thoroughly know, understand, and appreciate the risks involved. I authorize Shawn O. Henry, and such assistants as he might designate, to administer and conduct the tests as safely as possible and with a minimum of discomfort.

---

Signature of Subject

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Date

---

Signature of Witness

---

Date



**APPENDIX B**  
**MEDICAL HISTORY QUESTIONNAIRE**

## SUBJECT INFORMATION AND MEDICAL QUESTIONNAIRE

Name \_\_\_\_\_ Number \_\_\_\_\_ Date \_\_\_\_\_

Height \_\_\_\_\_ in x 2.54 = \_\_\_\_\_ cm

Mass \_\_\_\_\_ lb / 2.2 = \_\_\_\_\_ kg

Before participating in this study please answer the following questions:

YES      NO

-----

\_\_\_\_\_ Has your doctor ever said you had heart trouble?

\_\_\_\_\_ Do you ever feel faint or have spells of dizziness?

\_\_\_\_\_ Has your doctor ever said your blood pressure was too high?

\_\_\_\_\_ Has your doctor ever told you that you have a bone or joint problem that has been aggravated by exercise, or might be made worse with exercise?

\_\_\_\_\_ Do you have a family history of premature coronary artery disease?

\_\_\_\_\_ Have you had a neurologic disorder of the lower extremities?

\_\_\_\_\_ Have you had an orthopedic disorder of the lower extremities?

COMMENTS:

Responses to these questions will be analyzed by the principal investigator to determine the subjects suitability for this study. Subjects with previous or current neurological or orthopedic disorders of the lower extremities are excluded from this study. However, because this study does not involve any type of aerobic exercise, the analysis of the first five questions is more subjective in nature.

This form has been adapted from the questionnaire contained in Exercise and Your Heart, published by the U.S. Department of Health and Human Services, NIH Publication 381-1677, May 1981.

**APPENDIX C**  
**PROCEDURE SHEET FOR EXPERIMENTAL GROUP**

### STEPS FOR EXPERIMENTAL

1. THOROUGHLY ACQUAINT THE SUBJECT WITH ALL PROCEDURES (also fill out medical questionnaire and informed consent)
2. ANSWER ANY QUESTIONS OF THE SUBJECT
3. CHECK CAMERA
4. SEAT SUBJECT IN RACK
5. CLEAN OFF AREAS WHERE EMG, GROUND, AND MARKINGS WILL BE PLACED (USING ALCOHOL AND COTTON BALLS)
6. PLACE TAPE MARKINGS ON SUBJECT
7. AFTER PREPARING EMG CONTACTS, HAVE SUBJECT PALPATE ADDUCTORS AND PLACE THE EMG ON THEMSELVES. THE PRINCIPAL INVESTIGATOR WILL CHECK TO ASSURE PROPER POSITIONING.
8. PLACE EMG GROUND ON SUBJECT
9. TURN OSCILLISCOPE ON
10. TURN EMG ON (FROM STANDBY)
11. TESTING

PHOTO #1 (Pretest)

30 seconds rest

PHOTO #2 (Pretest)

1 min. 30 sec. rest

5 sec. near maximal contraction of adductors

5 sec. submaximal contraction of abduction musculature

15 sec. relaxation during which time the subject cranks the "rack" further if possible

PHOTO #3

Repeat PNF, then PHOTO #4

Repeat PNF, then PHOTO #5

1 min. 30 sec. rest  
PHOTO #6 (Posttest)  
30 sec. rest  
PHOTO #7 (posttest)

12. TURN OFF OSCILLISCOPE AND RETURN EMG TO STANDBY
13. REMOVE EMG, GROUND, AND MARKERS
14. CLEAN WITH ALCOHOL
15. TURN OFF CAMERA IF FINISHED

**APPENDIX D**  
**PROCEDURE SHEET FOR CONTROL GROUP**

### **STEPS FOR CONTROL**

1. THOROUGHLY ACQUAINT THE SUBJECT WITH ALL PROCEDURES (also fill out medical questionnaire and informed consent)
2. ANSWER ANY QUESTIONS OF THE SUBJECT
3. CHECK CAMERA
4. SEAT SUBJECT IN RACK
5. CLEAN OFF AREAS WHERE EMG, GROUND, AND MARKINGS WILL BE PLACED (USING ALCOHOL AND COTTON BALLS)
6. PLACE TAPE MARKINGS ON SUBJECT
7. AFTER PREPARING EMG CONTACTS, HAVE SUBJECT PALPATE ADDUCTORS AND PLACE THE EMG ON THEMSELVES. THE PRINCIPAL INVESTIGATOR WILL CHECK TO ASSURE PROPER POSITIONING.
8. PLACE EMG GROUND ON SUBJECT
9. TURN OSCILLISCOPE ON
10. TURN EMG ON (FROM STANDBY)
11. TESTING

PHOTO #1 (Pretest)

30 seconds rest

PHOTO #2 (Pretest)

4 min. 15 sec. rest and relaxation

PHOTO #3 (Posttest)

30 sec. rest

PHOTO #4 (posttest)

12. **TURN OFF OSCILLISCOPE AND RETURN EMG TO STANDBY**
13. **REMOVE EMG, GROUND, AND MARKERS**
14. **CLEAN WITH ALCOHOL**
15. **TURN OFF CAMERA IF FINISHED**



**APPENDIX E**  
**DATA COLLECTION SHEET**

**SUBJECT DATA SHEET****Experimental Group****Number** \_\_\_\_\_ **Date** \_\_\_\_\_  
Mo/Day/Yr**Photo #1** \_\_\_\_\_**Pretest****Photo #2** \_\_\_\_\_**Photo #3** \_\_\_\_\_**Photo #4** \_\_\_\_\_**Photo #5** \_\_\_\_\_**Photo #6** \_\_\_\_\_**Posttest****Photo #7** \_\_\_\_\_**Comments:**

**SUBJECT DATA SHEET****Control Group**

**Number** \_\_\_\_\_ **Date** \_\_\_\_\_  
Mo/Day/Yr

**Photo #1** \_\_\_\_\_

**Pretest**

**Photo #2** \_\_\_\_\_

**Photo #3** \_\_\_\_\_

**Posttest**

**Photo #4** \_\_\_\_\_

**Comments:**